

Calculation of the pressure drop in the absorber

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Goal

This program permits us to determine the approximate pressure drop in the absorber.

Note- assumption:

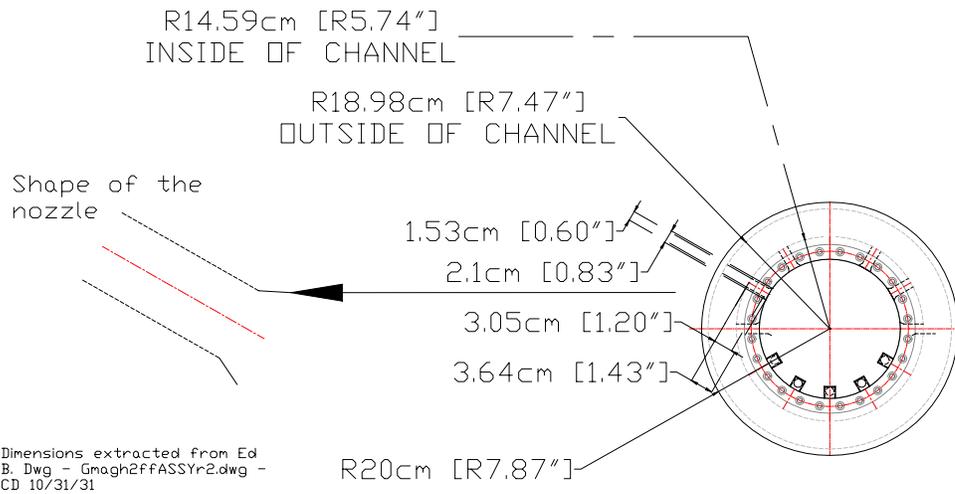
- 2D analysis.

Parameters

- Hydrogen mass flow: 63 g/s

- Pressure/temperature of Hydrogen: 1.2b/17K

Schematic: to update



Results

1-Total pressure drop to the pump = 4.27E-3 psig

Comments:

- Pressure drop should be lower than 0.032 psig, therefore this system is feasible.

1. MATERIAL PROPERTIES

Specific properties of Hydrogen at 1.2 bar - Data from GASPAK

Yh2 := READPRN("H2_1_2AT.prn")

$$\text{Temp} := \text{Yh2}^{(1)} \cdot \text{K}$$

$$\rho_{\text{H2}} := \text{Yh2}^{(2)} \cdot \frac{\text{kg}}{\text{m}^3}$$

$$\rho_{\text{H2}}(\text{T}) := \text{linterp}(\text{Temp}, \rho_{\text{H2}}, \text{T})$$

$$c_{\text{pH2}} := \text{Yh2}^{(5)} \cdot \frac{\text{joule}}{\text{kg} \cdot \text{K}}$$

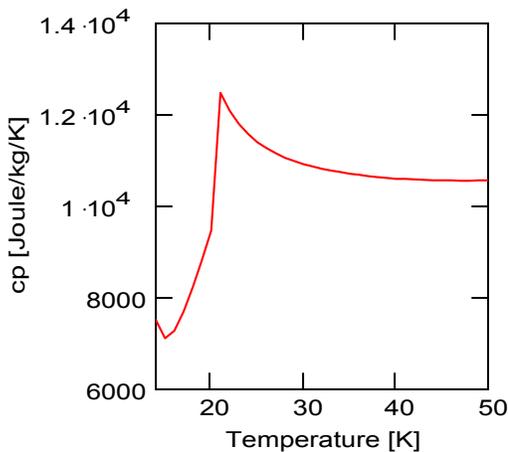
$$c_{\text{pH2}}(\text{T}) := \text{linterp}(\text{Temp}, c_{\text{pH2}}, \text{T})$$

$$\text{HH2} := \text{Yh2}^{(6)} \cdot \frac{\text{joule}}{\text{kg}}$$

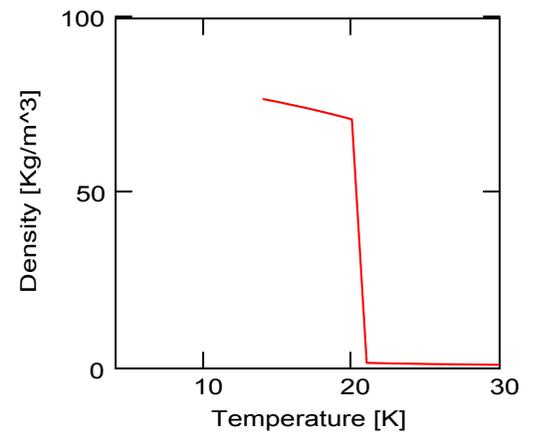
$$\text{HH2}(\text{T}) := \text{linterp}(\text{Temp}, \text{HH2}, \text{T})$$

$$c_{\text{pH2}}(14 \cdot \text{K}) = 7.516 \times 10^3 \text{ kg}^{-1} \text{ K}^{-1} \text{ joule}$$

$$\text{T} := 14.. 50$$



$$\text{T} := 0 \cdot \text{K}.. 300 \cdot \text{K}$$



density

viscosity

conductivity

specific heat

enthalpy

$$\rho_{\text{H2}} := \text{Yh2}^{(2)} \cdot \frac{\text{kg}}{\text{m}^3}$$

$$\mu_{\text{H2}} := \text{Yh2}^{(3)} \cdot \text{Pa} \cdot \text{sec}$$

$$k_{\text{H2}} := \text{Yh2}^{(4)} \cdot \frac{\text{watt}}{\text{m} \cdot \text{K}}$$

$$c_{\text{pH2}} := \text{Yh2}^{(5)} \cdot \frac{\text{joule}}{\text{kg} \cdot \text{K}}$$

$$\text{HH2} := \text{Yh2}^{(6)} \cdot \frac{\text{joule}}{\text{kg}}$$

$$\rho_{\text{H2}}(\text{T}) := \text{linterp}(\text{Temp}, \rho_{\text{H2}}, \text{T})$$

$$\rho_{\text{H2}}(18 \cdot \text{K}) = 73.3 \text{ kg m}^{-3}$$

$$\mu_{\text{H2}}(\text{T}) := \text{linterp}(\text{Temp}, \mu_{\text{H2}}, \text{T})$$

$$\mu_{\text{H2}}(18 \cdot \text{K}) = 1.673 \times 10^{-5} \text{ kg m}^{-1} \text{ sec}^{-1}$$

$$k_{\text{H2}}(\text{T}) := \text{linterp}(\text{Temp}, k_{\text{H2}}, \text{T})$$

$$k_{\text{H2}}(18 \cdot \text{K}) = 0.101 \text{ kg m sec}^{-3} \text{ K}^{-1}$$

$$c_{\text{pH2}}(\text{T}) := \text{linterp}(\text{Temp}, c_{\text{pH2}}, \text{T})$$

$$c_{\text{pH2}}(18 \cdot \text{K}) = 8.232 \times 10^3 \text{ m}^2 \text{ sec}^{-2} \text{ K}^{-1}$$

$$\text{HH2}(\text{T}) := \text{linterp}(\text{Temp}, \text{HH2}, \text{T})$$

$$\text{HH2}(18 \cdot \text{K}) = -2.478 \times 10^5 \text{ kg}^{-1} \text{ joule}$$

2. DATA - input

$$\text{Le} := 74 \cdot \text{m}$$

$$\text{Nnsupplydia} := 8$$

$$\text{Nport} := 2$$

$$\text{Nnsupplystraight} := 5$$

$$\text{NTL} := \text{Nport}$$

$$\text{Nnreturnstraight} := 7$$

$$\text{Nnsupply} := \text{Nnsupplydia} + \text{Nnsupplystraight}$$

$$\text{Nnreturndia} := 12$$

$$\text{Nnreturn} := \text{Nnreturndia} + \text{Nnreturnstraight}$$

$$\text{Nnsupply} = 13$$

$$\text{Nnreturn} = 19$$

$$\text{Nnozzle} := \text{Nnsupply} + \text{Nnreturn}$$

$$\text{Nnozzle} = 32$$

$$\text{m\dot{o}h2tot} := 63 \cdot 10^{-3} \cdot \frac{\text{kg}}{\text{sec}}$$

$$\text{m\dot{o}h2supply} := \frac{\text{m\dot{o}h2tot}}{\text{Nnsupply}}$$

$$\text{m\dot{o}h2return} := \frac{\text{m\dot{o}h2tot}}{\text{Nnreturn}}$$

$$\text{m\dot{o}h2port} := \frac{\text{m\dot{o}h2tot}}{\text{Nport}}$$

$$\text{m\dot{o}h2TL} := \text{m\dot{o}h2port}$$

$$\text{m\dot{o}h2TLreturn} := \text{m\dot{o}h2port} \cdot \frac{2}{3}$$

$$\text{m\dot{o}h2supply} = 4.846 \times 10^{-3} \text{ kg sec}^{-1}$$

$$\text{m\dot{o}h2return} = 3.316 \times 10^{-3} \text{ kg sec}^{-1}$$

$$\text{m\dot{o}h2port} = 0.032 \text{ kg sec}^{-1}$$

$$\text{m\dot{o}h2TL} = 0.032 \text{ kg sec}^{-1}$$

2.1. Set of temperatures:

$$\text{Th2in} := 17.3 \cdot \text{K}$$

$$\text{Th2out} := 17 \cdot \text{K}$$

2.2. Geometry

Nozzles

$$\text{Lestraightsupply} := 2.23 \cdot \text{in}$$

$$\text{Lediastupply} := 1.56 \cdot \text{in}$$

$$\text{Lestraightreturn} := 1.21 \cdot \text{in}$$

$$\text{Lediareturn} := 1.58 \cdot \text{in}$$

$$\text{dcth2} := 0.75 \cdot \text{in}$$

$$\text{Ah2} := \left[\pi \cdot \left(\frac{\text{dcth2}}{2} \right)^2 \right]$$

$$\text{Ah2} = 2.85 \times 10^{-4} \text{ m}^2$$

Ports

$$\text{dcth2port} := 2 \cdot 0.52 \cdot \text{in}$$

$$\text{Ah2port} := \pi \cdot \left(\frac{\text{dcth2port}}{2} \right)^2$$

$$\text{Ah2port} = 5.481 \times 10^{-4} \text{ m}^2$$

$$\text{Leport} := (2.85 + 2.37) \cdot \text{in}$$

$$\text{Leport} = 0.133 \text{ m}$$

Transfer line

$$\text{dh2TL} := 1 \cdot \text{in}$$

$$\text{dh2TLcontr} := 1.73 \cdot \text{in}$$

$$\text{LeTL} := 21.42 \cdot \text{in}$$

$$\text{dh2TLexp} := 0.012 \cdot \text{m}$$

$$\text{dh2TLHX} := 2 \cdot \text{in}$$

Calculated from "flow of incompressible newtonian fluids in pipes, p25"

$$\text{Ah2TL} := \left[\pi \cdot \left(\frac{\text{dh2TL}}{2} \right)^2 \right]$$

$$\text{Ah2TL} = 5.067 \times 10^{-4} \text{ m}^2$$

$$\text{Ah2TLexp} := \left[\pi \cdot \left(\frac{\text{dh2TLexp}}{2} \right)^2 \right]$$

$$\text{Ah2TLexp} = 1.131 \times 10^{-4} \text{ m}^2$$

$$\text{Ah2TLcontr} := \left[\pi \cdot \left(\frac{\text{dcth2}}{2} \right)^2 \right]$$

$$\text{Ah2TLcontr} = 2.85 \times 10^{-4} \text{ m}^2$$

$$\text{Ah2TLHX} := \left[\pi \cdot \left(\frac{\text{dh2TLHX}}{2} \right)^2 \right]$$

$$\text{Ah2TLHX} = 2.027 \times 10^{-3} \text{ m}^2$$

HX - outer shell

$$\text{Did} := 6 \cdot \text{in}$$

$$\text{Dred} := 3 \cdot \text{in}$$

$$\text{AH2} := 3.14 \cdot \frac{\left[\left(\text{Did} - 2 \cdot \frac{5 \cdot \text{in}}{8} \right)^2 - \text{Dred}^2 \right]}{4} \quad \text{AH2} = 6.869 \times 10^{-3} \text{ m}^2$$

$$\text{Per} := 3.14 \cdot (\text{Did} + \text{Dred})$$

$$\text{DHXh} := 4 \cdot \frac{\text{AH2}}{\text{Per}} \quad \text{Hydraulic diameter: DHXh} = 0.038 \text{ m}$$

$$\text{LHX} := 20 \cdot \text{in}$$

$$\text{AHX} := \left[\pi \cdot \left(\frac{\text{DHXh}}{2} \right)^2 \right] \quad \text{cross-section area H2}$$

$$\text{AHX} = 1.151 \times 10^{-3} \text{ m}^2$$

3. COOLING SCHEME:

3.1. Forced convection heat transfer coefficients (turbulent flow)

$$\text{Pr}(\mu, \text{cp}, \text{k}, \text{T}) := \mu(\text{T}) \cdot \frac{\text{cp}(\text{T})}{\text{k}(\text{T})} \quad \text{Prandtl number}$$

$$\text{Re}(\rho, \text{v}, \text{d}, \mu, \text{T}) := \rho(\text{T}) \cdot \text{v} \cdot \frac{\text{d}}{\mu(\text{T})} \quad \text{Reynolds number}$$

$$\text{Nu}(\text{Re}, \text{Pr}) := 0.023 \cdot \text{Re}^{0.8} \cdot \text{Pr}^{0.4} \quad \text{Nusselt number - helium -inner side}$$

$$\text{h}(\text{Nu}, \text{k}, \text{T}, \text{d}) := \text{Nu} \cdot \frac{\text{k}(\text{T})}{\text{d}} \quad \text{convection heat transfer coefficient for natural convection in monophasic He}$$

$$\text{vh2}(\text{m}, \text{A}, \rho, \text{T}) := \frac{\text{m}}{\text{A} \cdot \rho(\text{T})}$$

$$\text{Th2} := \text{Th2in} + \frac{\text{Th2out} - \text{Th2in}}{2}$$

3.2. Hydrogen flow velocities

$$\text{Prh2} := \text{Pr}(\mu\text{H2}, \text{cpH2}, \text{kH2}, \text{Th2})$$

$$\text{Prh2} = 1.431$$

$$\text{vH2return} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2return}, \text{Ah2}, \rho\text{H2}, \text{Th2}) \quad \text{Velocity at the return nozzle} \quad \text{vH2return} = 0.157 \text{ m sec}^{-1}$$

$$\text{vH2supply} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2supply}, \text{Ah2}, \rho\text{H2}, \text{Th2}) \quad \text{Velocity at the supply nozzle} \quad \text{vH2supply} = 0.229 \text{ m sec}^{-1}$$

$$\text{vH2port} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2port}, \text{Ah2port}, \rho\text{H2}, \text{Th2}) \quad \text{Velocity at the common port} \quad \text{vH2port} = 0.775 \text{ m sec}^{-1}$$

$$\text{vH2TL} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2TL}, \text{Ah2TL}, \rho\text{H2}, \text{Th2}) \quad \text{vH2TL} = 0.839 \text{ m sec}^{-1}$$

$$\text{vH2TLexp} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2TLexp}, \text{Ah2TLexp}, \rho\text{H2}, \text{Th2}) \quad \text{vH2TLexp} = 3.757 \text{ m sec}^{-1}$$

$$\text{vH2contr} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2contr}, \text{Ah2TLcontr}, \rho\text{H2}, \text{Th2}) \quad \text{vH2contr} = 0.229 \text{ m sec}^{-1}$$

$$\text{vH2TLreturn} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2TLreturn}, \text{Ah2TL}, \rho\text{H2}, \text{Th2}) \quad \text{vH2TLreturn} = 0.559 \text{ m sec}^{-1}$$

$$\text{vH2TLHX} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2TLHX}, \text{Ah2TLHX}, \rho\text{H2}, \text{Th2}) \quad \text{vH2TLHX} = 0.419 \text{ m sec}^{-1}$$

$$\text{vH2HX} := \text{vh2}(\text{m}\dot{\text{v}}\text{H2HX}, \text{AhX}, \rho\text{H2}, \text{Th2}) \quad \text{vH2HX} = 0.739 \text{ m sec}^{-1}$$

$$\text{Reh2supply} := \text{Re}(\rho\text{H2}, \text{vH2supply}, \text{dcth2}, \mu\text{H2}, \text{Th2}) \quad \text{Reh2supply} = 1.794 \times 10^4$$

$$\text{Reh2return} := \text{Re}(\rho\text{H2}, \text{vH2return}, \text{dcth2}, \mu\text{H2}, \text{Th2}) \quad \text{Reh2return} = 1.227 \times 10^4$$

$$\text{Reh2port} := \text{Re}(\rho\text{H2}, \text{vH2port}, \text{dcth2port}, \mu\text{H2}, \text{Th2}) \quad \text{Reh2port} = 8.408 \times 10^4$$

$$\text{Reh2TL} := \text{Re}(\rho\text{H2}, \text{vH2TL}, \text{dh2TL}, \mu\text{H2}, \text{Th2}) \quad \text{Reh2TL} = 8.745 \times 10^4$$

$$\text{Reh2TLexp} := \text{Re}(\rho\text{H2}, \text{vH2TLexp}, \text{dh2TLexp}, \mu\text{H2}, \text{Th2}) \quad \text{Reh2TLexp} = 1.851 \times 10^5$$

$$\begin{aligned} \text{Reh2contr} &:= \text{Re}(\rho\text{H2}, \text{vH2contr}, \text{dcth2}, \mu\text{H2}, \text{Th2}) \\ \text{Reh2TLreturn} &:= \text{Re}(\rho\text{H2}, \text{vH2TLreturn}, \text{dh2TL}, \mu\text{H2}, \text{Th2}) \\ \text{Reh2TLHX} &:= \text{Re}(\rho\text{H2}, \text{vH2TLHX}, \text{dh2TLHX}, \mu\text{H2}, \text{Th2}) \\ \text{Reh2HX} &:= \text{Re}(\rho\text{H2}, \text{vH2HX}, \text{DHXh}, \mu\text{H2}, \text{Th2}) \end{aligned}$$

$$\begin{aligned} \text{Reh2contr} &= 1.794 \times 10^4 \\ \text{Reh2TLreturn} &= 5.83 \times 10^4 \\ \text{Reh2TLHX} &= 8.745 \times 10^4 \\ \text{Reh2HX} &= 1.161 \times 10^5 \end{aligned}$$

$$\text{Nuh2supply} := \text{Nu}(\text{Reh2supply}, \text{Prh2})$$

$$\text{Nuh2supply} = 67.136$$

$$\text{Nuh2return} := \text{Nu}(\text{Reh2return}, \text{Prh2})$$

$$\text{Nuh2return} = 49.557$$

$$\text{Nuh2port} := \text{Nu}(\text{Reh2port}, \text{Prh2})$$

$$\text{Nuh2port} = 231.052$$

$$\text{Nuh2TL} := \text{Nu}(\text{Reh2TL}, \text{Prh2})$$

$$\text{Nuh2TL} = 238.417$$

$$\text{Nuh2TLexp} := \text{Nu}(\text{Reh2TLexp}, \text{Prh2})$$

$$\text{Nuh2TLexp} = 434.369$$

$$\text{Nuh2contr} := \text{Nu}(\text{Reh2contr}, \text{Prh2})$$

$$\text{Nuh2contr} = 67.136$$

$$\text{Nuh2TLreturn} := \text{Nu}(\text{Reh2TLreturn}, \text{Prh2})$$

$$\text{Nuh2TLreturn} = 172.371$$

$$\text{Nuh2TLHX} := \text{Nu}(\text{Reh2TLHX}, \text{Prh2})$$

$$\text{Nuh2TLHX} = 238.417$$

$$\text{Nuh2HX} := \text{Nu}(\text{Reh2HX}, \text{Prh2})$$

$$\text{Nuh2HX} = 299.008$$

$$\text{hcth2supply} := \text{h}(\text{Nuh2supply}, \text{kH2}, \text{Th2}, \text{dcth2})$$

$$\text{hcth2supply} = 0.035 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2return} := \text{h}(\text{Nuh2return}, \text{kH2}, \text{Th2}, \text{dcth2})$$

$$\text{hcth2return} = 0.026 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2port} := \text{h}(\text{Nuh2port}, \text{kH2}, \text{Th2}, \text{dcth2port})$$

$$\text{hcth2port} = 0.086 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2TL} := \text{h}(\text{Nuh2TL}, \text{kH2}, \text{Th2}, \text{dh2TL})$$

$$\text{hcth2TL} = 0.092 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2TLexp} := \text{h}(\text{Nuh2TLexp}, \text{kH2}, \text{Th2}, \text{dh2TLexp})$$

$$\text{hcth2TLexp} = 0.355 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2contr} := \text{h}(\text{Nuh2contr}, \text{kH2}, \text{Th2}, \text{dcth2})$$

$$\text{hcth2contr} = 0.035 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2TLreturn} := \text{h}(\text{Nuh2TLreturn}, \text{kH2}, \text{Th2}, \text{dh2TL})$$

$$\text{hcth2TLreturn} = 0.067 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2TLHX} := \text{h}(\text{Nuh2TLHX}, \text{kH2}, \text{Th2}, \text{dh2TLHX})$$

$$\text{hcth2TLHX} = 0.046 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\text{hcth2HX} := \text{h}(\text{Nuh2HX}, \text{kH2}, \text{Th2}, \text{DHXh})$$

$$\text{hcth2HX} = 0.077 \text{ K}^{-1} \frac{\text{watt}}{\text{cm}^2}$$

$$\rho\text{H2} := \rho\text{H2}(\text{Th2})$$

$$\rho\text{H2} = 74.136 \text{ kg m}^{-3}$$

3.3. Hydrogen Cooling Capacity - information ...

$$\rho\text{H2}(\text{m\dot{o}th2}, \text{Th2out}, \text{Th2in}) := \frac{-[\text{m\dot{o}th2} \cdot \text{cpH2}(\text{Th2}) \cdot (\text{Th2out} - \text{Th2in})]}{\text{Le}} \quad \rho\text{H2}(\text{m\dot{o}th2tot}, \text{Th2out}, \text{Th2in}) = 1.985 \text{ m}^{-1} \text{ watt}$$

4. Pressure drop calculations

$$\text{Reh2supply} = 1.794 \times 10^4$$

Blasius expression for $\text{Re} < 10^5$...

4.1. In Hydrogen circuit supply

$$\rho\text{H2} = 74.136 \text{ kg m}^{-3}$$

$$\text{fh2contr} := 0.079 \cdot \text{Reh2contr}^{-1/4}$$

$$\text{fh2supply} := 0.00332 + \frac{0.221}{\text{Reh2supply}^{0.237}}$$

$$\text{vH2supply} = 0.229 \text{ m sec}^{-1}$$

$$\text{fh2supply} = 0.025$$

$$\text{droph2supplystraight} := 30\text{fh2supply} \cdot \frac{\rho_{\text{H2}} \cdot v_{\text{H2supply}}^2}{2}$$

$$\text{droph2supplystraight} = 2.122 \times 10^{-4} \text{ psi}$$

$$\text{droph2supplydia1} := 0.7 \cdot \frac{\rho_{\text{H2}} \cdot v_{\text{H2supply}}^2}{2}$$

$$\text{droph2supplydia1} = 1.979 \times 10^{-4} \text{ psi}$$

$$\text{droph2supplydia2} := 25\text{fh2supply} \cdot \frac{\rho_{\text{H2}} \cdot v_{\text{H2supply}}^2}{2}$$

$$\text{droph2supplydia2} = 1.768 \times 10^{-4} \text{ psi}$$

$$\text{droph2supplydia3} := \text{fh2supply} \cdot \frac{\text{Lestraightsupply} \cdot \rho_{\text{H2}} \cdot v_{\text{H2supply}}^2}{\text{dcth2} \cdot 2}$$

$$\text{droph2supplydia3} = 2.103 \times 10^{-5} \text{ psi}$$

$$\text{droph2supply} := \text{droph2supplydia3} + \text{droph2supplydia1} + \text{droph2supplydia2} + \text{droph2supplystraight}$$

$$\text{droph2supply} = 6.08 \times 10^{-4} \text{ psi}$$

4.2. In the common supply port $\text{Reh2port} = 8.408 \times 10^4$

$$\text{fh2port} := 0.00332 + \frac{0.221}{\text{Reh2port}^{0.237}}$$

$$\rho_{\text{H2}} = 74.136 \text{ kg m}^{-3}$$

$$v_{\text{H2port}} = 0.775 \text{ m sec}^{-1}$$

$$\text{fh2port} = 0.018$$

$$\text{Leportequi} := 30 \cdot \text{dcth2port}$$

$$\text{droph2port} := \text{fh2port} \cdot \frac{\rho_{\text{H2}} \cdot v_{\text{H2port}}^2}{2}$$

$$\text{droph2port} = 0.409 \text{ Pa}$$

$$\text{droph2port} = 5.933 \times 10^{-5} \text{ psi}$$

4.3. supply TL line $\text{Reh2TL} = 8.745 \times 10^4$

$$\text{dh2TL} = 0.025 \text{ m}$$

$$\text{LeTL} = 0.544 \text{ m}$$

$$\rho_{\text{H2}} = 74.136 \text{ kg m}^{-3}$$

$$v_{\text{H2TL}} = 0.839 \text{ m sec}^{-1}$$

$$\text{fh2TL} := 0.00332 + \frac{0.221}{\text{Reh2TL}^{0.237}}$$

$$\text{fh2TL} = 0.018$$

$$\text{droph2TL} := \text{fh2TL} \cdot \frac{\text{LeTL} \cdot \rho_{\text{H2}} \cdot v_{\text{H2TL}}^2}{\text{dh2TL} \cdot 2}$$

$$\text{droph2TL} = 10.172 \text{ Pa}$$

$$\text{droph2TL} = 1.475 \times 10^{-3} \text{ psi}$$

4.4. return Transfer line $\text{Reh2TL} = 8.745 \times 10^4$

$$\text{dh2TL} = 0.025 \text{ m}$$

$$\text{LeTL} = 0.544 \text{ m}$$

$$\text{fh2TLreturn} := 0.00332 + \frac{0.221}{\text{Reh2TLreturn}^{0.237}}$$

$$\rho_{\text{H2}} = 74.136 \text{ kg m}^{-3}$$

$$v_{\text{H2TL}} = 0.839 \text{ m sec}^{-1}$$

$$\text{fh2TL} = 0.018$$

$$\text{droph2TLreturn} := \text{fh2TLreturn} \cdot \frac{\text{LeTL} \cdot \rho_{\text{H2}} \cdot v_{\text{H2TLreturn}}^2}{\text{dh2TL} \cdot 2}$$

$$\text{droph2TL} = 10.172 \text{ Pa}$$

$$\text{droph2TLreturn} = 7.098 \times 10^{-4} \text{ psi}$$

4.5 Transfer line to HX

$$\text{Reh2TL} = 8.745 \times 10^4 \quad \text{dh2TL} = 0.025 \text{ m}$$

$$\text{LeTL} = 0.544 \text{ m}$$

$$\text{dh2TL} = 1 \text{ in}$$

$$f_{H2TLHX} := 0.00332 + \frac{0.221}{Re_{H2TLHX}^{0.237}} \quad \rho_{H2} = 74.136 \text{ kg m}^{-3}$$

$$v_{H2TLHX} = 0.419 \text{ m sec}^{-1} \quad f_{H2TLHX} = 0.018$$

$$d_{ropH2TLHX} := f_{H2TLHX} \cdot \frac{L_{eTL} \cdot \rho_{H2} \cdot v_{H2TLHX}^2}{d_{H2TL} \cdot 2} \quad d_{ropH2TLHX} = 2.543 \text{ Pa} \quad d_{ropH2TLHX} = 3.688 \times 10^{-4} \text{ psi}$$

4.6. Supply line - sudden expansion

$$Re_{H2TLexp} = 1.851 \times 10^5$$

$$f_{H2TLexp} := 0.00332 + \frac{0.221}{Re_{H2TLexp}^{0.237}}$$

Value from "Flow of incompressible newtonian fluids in pipes p25)

$$g := 32.2 \cdot \frac{\text{ft}}{\text{sec}^2}$$

$$D_{exp} := d_{H2TLcontr}$$

$$\beta_{exp} := \frac{d_{exp}}{D_{exp}} \quad \beta_{exp} = 0.578$$

$$d_{exp} := d_{H2TL}$$

$$f_{H2TLexp} = 0.016$$

$$r_{exp} := \frac{1}{4} f_{H2TLexp} \cdot (1 - \beta_{exp}^2)^2 \quad r_{exp} = 1.751 \times 10^{-3}$$

$$DP_{exp} := r_{exp} \cdot f_{H2TLexp} \cdot \frac{v_{H2TLexp}^2 \cdot \rho_{H2}}{2}$$

$$DP_{exp} = 2.098 \times 10^{-6} \text{ psi}$$

4.7. Supply line - sudden compression

$$Re_{H2contr} = 1.794 \times 10^4$$

$$D_{contr} := d_{H2TLcontr}$$

$$f_{H2contr} := 0.00332 + \frac{0.221}{Re_{H2contr}^{0.237}}$$

$$d_{contr} := d_{ch2}$$

$$\beta_{contr} := \frac{d_{contr}}{D_{contr}}$$

$$\beta_{contr} = 0.434$$

$$r_{contr} := \frac{1}{10} f_{H2contr} \cdot (1.25 - \beta_{exp}^2)$$

$$r_{contr} = 2.291 \times 10^{-3}$$

$$f_{H2contr} = 0.025$$

$$DP_{contr} := r_{contr} \cdot f_{H2contr} \cdot \frac{v_{H2contr}^2 \cdot \rho_{H2}}{2}$$

$$DP_{contr} = 1.62 \times 10^{-8} \text{ psi}$$

4.8 To HX w/ 3" reduction section

$$Re_{H2HX} = 1.161 \times 10^5 \quad D_{HXh} = 0.038 \text{ m}$$

$$L_{HX} = 0.508 \text{ m}$$

$$f_{H2HX} := 0.00332 + \frac{0.221}{Re_{H2HX}^{0.237}}$$

$$\rho_{H2} = 74.136 \text{ kg m}^{-3}$$

$$v_{H2HX} = 0.739 \text{ m sec}^{-1}$$

$$f_{H2HX} = 0.017$$

$$d_{ropH2HX} := f_{H2HX} \cdot \frac{L_{HX} \cdot \rho_{H2} \cdot v_{H2HX}^2}{D_{HXh} \cdot 2}$$

$$d_{ropH2HX} = 4.629 \text{ Pa}$$

$$d_{ropH2HX} = 6.714 \times 10^{-4} \text{ psi}$$

4.8. In Hydrogen circuit return

$$Re_{H2return} = 1.227 \times 10^4$$

$$f_{H2return} := 0.00332 + \frac{0.221}{Re_{H2return}^{0.237}}$$

$$\rho_{H2} = 74.136 \text{ kg m}^{-3}$$

$$v_{H2return} = 0.157 \text{ m sec}^{-1} \quad f_{H2return} = 0.027$$

$$d_{ropH2returndia1} := 30 f_{H2return} \cdot \frac{\rho_{H2} \cdot v_{H2return}^2}{2}$$

$$d_{ropH2returndia1} = 1.074 \times 10^{-4} \text{ psi}$$

$$\text{droph2returndia2} := 25f_{h2return} \cdot \frac{\rho_{H2} \cdot v_{H2return}^2}{2}$$

$$\text{droph2returndia2} = 8.953 \times 10^{-5} \text{ psi}$$

$$\text{droph2returndia3} := f_{h2return} \cdot \frac{L_{ediareturn} \cdot \rho_{H2} \cdot v_{H2return}^2}{d_{ch2} \cdot 2}$$

$$\text{droph2returndia3} = 7.544 \times 10^{-6} \text{ psi}$$

$$\text{droph2returnstraight} := 30f_{h2return} \cdot \frac{\rho_{H2} \cdot v_{H2return}^2}{2}$$

$$\text{droph2returnstraight} = 1.074 \times 10^{-4} \text{ psi}$$

$$\text{droph2return} := \text{droph2returndia1}^{\blacksquare}$$

$$\text{droph2return} := \text{droph2returndia1} + \text{droph2returndia2} + \text{droph2returndia3} + \text{droph2returnstraight}$$

$$\text{droph2return} = 3.119 \times 10^{-4} \text{ psi}$$

We made the assumption that the pressure drop due to sudden exp and contr at the in/outlet of the TI is equivalent

SUMMARY - TOTAL PRESSURE DROP

$$\text{drop} := \text{droph2supply} + \text{droph2return} + \text{droph2TLHX} + \text{droph2TL} + \text{droph2HX} + \text{droph2TLreturn} + 2 \cdot (\text{droph2port} + \text{DP}_{exp} + \text{DP}_{contr})$$

With a 3" diameter reduction in the HX volume

$$\text{drop} = 4.268 \times 10^{-3} \text{ psi}$$

$$\text{drop} = 29.429 \text{ Pa}$$

$$\text{droph2supply} = 6.08 \times 10^{-4} \text{ psi}$$

$$\text{droph2supply} = 4.192 \text{ Pa}$$

$$\text{droph2return} = 3.119 \times 10^{-4} \text{ psi}$$

$$\text{droph2return} = 2.151 \text{ Pa}$$

$$\text{droph2TL} = 1.475 \times 10^{-3} \text{ psi}$$

$$\text{droph2TL} = 10.172 \text{ Pa}$$

$$\text{droph2TLreturn} = 7.098 \times 10^{-4} \text{ psi}$$

$$\text{droph2TLreturn} = 4.894 \text{ Pa}$$

$$\text{droph2TLHX} = 3.688 \times 10^{-4} \text{ psi}$$

$$\text{droph2TLHX} = 2.543 \text{ Pa}$$

$$\text{DP}_{exp} = 2.098 \times 10^{-6} \text{ psi}$$

$$\text{DP}_{exp} = 0.014 \text{ Pa}$$

$$\text{DP}_{contr} = 1.62 \times 10^{-8} \text{ psi}$$

$$\text{DP}_{contr} = 1.117 \times 10^{-4} \text{ Pa}$$

$$\text{droph2port} = 5.933 \times 10^{-5} \text{ psi}$$

$$\text{droph2port} = 0.409 \text{ Pa}$$

$$\text{droph2HX} = 6.714 \times 10^{-4} \text{ psi}$$

$$\text{droph2HX} = 4.629 \text{ Pa}$$

contr)